NORTH - SOUTH SLOPE ASYMMETRIES ON MARS: STATISTICAL ANALYSIS OF MOLA DATA.
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Introduction: Mars Orbiter Laser Altimeter (MOLA) onboard Mars Global Surveyor (MGS) spacecraft produced a large homogeneous data set of precise elevation measurements along MGS tracks [1]. We have used this data set to map and study statistical characteristics of kilometer- and subkilometer-scale topography [e.g., 2, 3]. In the present work we use MOLA data set to map and study slope asymmetry on Mars. Slope asymmetry is an important parameter in processes related to insolation and water mobility.

Data processing: The direction of all MOLA tracks is close to meridianal except the high-latitude regions. The deflection from the meridian is about 5° in a wide equatorial zone. Poleward from 60° latitude, the deflection slowly, then more quickly increases, and reaches 17° at 80° latitude. Thus, sampling of Mars surface with MOLA is strongly anisotropic, and the data set does not allow complete study of slope anisotropy at subkilometer scale. The data can be used, however, to study the north - south asymmetry of the slopes.

The data processing technique we used was similar to that applied in [2] and [3]. For each pair of consecutive MOLA shots, we calculated the differential slope, keeping slope direction information (positive/negative sign was used for the south-/north-facing slopes). The differential slope was defined as the slope at 0.3 km baseline (the shot-to-shot distance) minus the slope at 0.9 km. The use of the differential slope instead of ordinary slope was necessary to eliminate the influence of regional topography on slope statistics. All calculated slopes were binned into map cells in a simple cylindrical projection; for each cell we calculated the median slope and the quartiles of the slope frequency distribution.

The difference between the quartiles characterizes the width of the slope-frequency distribution, and serves as a measure of roughness. It is very close to doubled median absolute value of the differential slope used in [2]. Fig. 1 shows the roughness map obtained in this way; brighter shades denote rougher surface. Major geomorphic features are clearly distinguishable in the map; the latitudinal trend of roughness (smoother terrains at high latitudes) is pronounced even more clearly than in [2, Fig. 12], because the baseline here is twice shorter.

The median signed slope can be used to quantify the deviation of the slope-frequency distribution from symmetric. The mean slope is always equal to zero. Nonzero median slope means a different balance of steep and gentle slopes for north- and south-facing surfaces. To eliminate roughness and characterize solely the distribution shape we divided the median by the quartile difference. The map of this parameter is shown in Fig. 2; brighter shades denote positive median slope. The positive median slope means that the area covered by south-facing slopes is greater than the area covered by north-facing slopes. Since the mean slope is zero, this means, that the north-facing slopes are generally steeper than south-facing slopes.

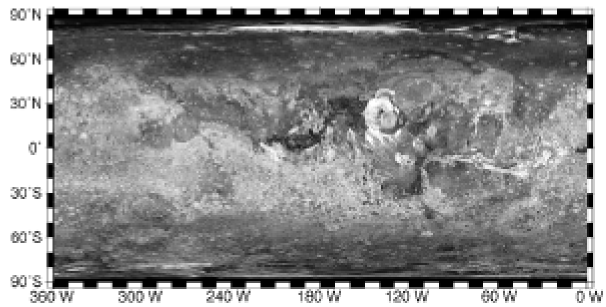

Fig. 1. Map of roughness at 0.3 km baseline. Brighter shades denote rougher surface.

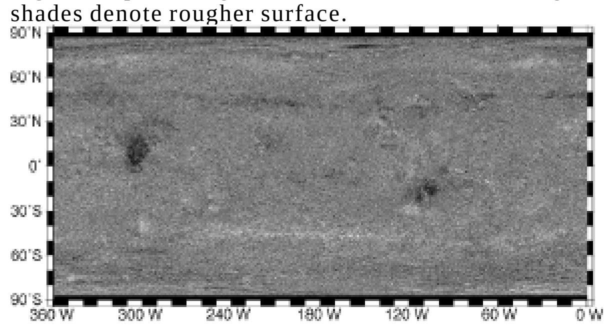

Fig. 2. Map of the north-south slope asymmetry. Brighter shades denote that north-facing slopes are steeper; darker shades denote that south-facing slopes are steeper.

Regions of slope asymmetry: The map of slope asymmetry (Fig. 2), although having a high noise level, shows clearly that most of the surface does not have any N - S slope asymmetry, excluding several distinctive areas. Small areas of prominent nonzero median slope at the highest latitudes are related to asymmetry the trough walls in the polar caps. Several areas of positive median slope at high north latitudes (~70°N) occur due to the interference of the deviation of MGS tracks from the meridian with strongly anisotropic topography of transverse dune fields.

A prominent feature of the map is a pair of narrow *latitudinal anomalous zones* at 40 - 50° in both hemispheres. The signs of the median slope in both hemispheres are opposite indicating that equator-facing slopes are steeper in these zones. Fig. 3 compares the shapes of the slope-frequency distributions for typical equatorial highlands (bold gray curve) and the southern anomalous zone in typical highland area (thin black curve). The anomalous zone is much smoother than the equatorial region due to the latitudinal trend of roughness (see Fig. 1; the quartile difference is 0.6° and 1.2°, respectively). To compare the distribution shapes in Fig. 3 we scaled slopes to the distribution width. Note the logarithmic scale of the vertical axis. Fig. 4 shows the same distributions "folded" along vertical axis to demonstrate the distribution asymmetry. The left pane of Fig. 4 shows that the positive and negative branches of the distribution for the "normal" highlands perfectly coincide. The relative difference between equator- and pole-faced slopes in the anomalous zone (Fig. 4, right pane) is higher for high slopes (>1°).

The strongest asymmetry is observed in a few regions in the equatorial zone. The region in south-east Arabia Terra, just to the west from Syrtis Major, and Syria Planum have the median slope of ~2.5% of the interquartile width of the slope distribution; S-facing slopes are steeper in these areas. An anomaly of the same sign is observed in north-east Daedalia Planum, and of the opposite sign in south-east Daedalia. The latter two areas are also anomalous in another statistical characteristics of topography: in this region there is strong prevalence of concave topography. There are several less pronounced local anomalies.

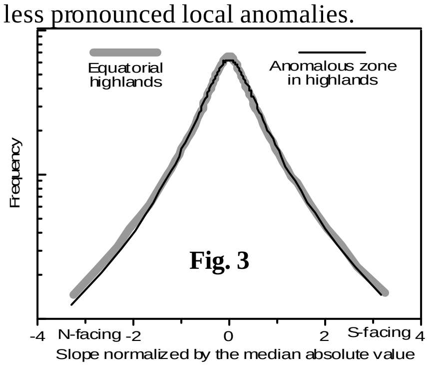

Fig. 3

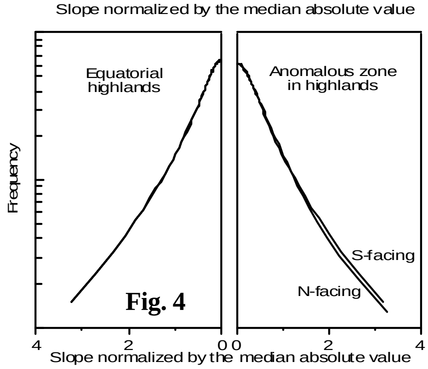

Fig. 4

Discussion of the latitudinal anomalous zones: The symmetry relatively the equator indicates the role of insolation in the formation of the anomalous zones. These zones are at the latitudes where the difference in insolation between pole- and equator-facing slopes is maximal. If the insolation asymmetry were the only primary reason for the effect, however, we would expect wider zones. The anomalous zones are close to the predicted boundary of the shallow subsurface ice stability [4], which can be a primary reason for the effect.

The anomalous zones coincide with transition from smoothed high-latitude to rougher low-latitude zones (see Fig. 1). The same anomalous zones also have a prevalence of convex topography, while typical equatorial highlands and smoothed high-latitude highlands have weak and strong prevalence of concave topography, respectively [3]. The anomalous zones roughly coincide with the boundaries of the young high-latitude mantle [3] seen in the high-resolution images. Erosion of this mantle produces dissected terrains [5]. In an accompanying abstract by Mustard et al. we compare the distribution of the observed dissection with the topographic characteristics. Boundaries of circumpolar regions of shallow subsurface ice observed by γ-ray and neutron spectrometers onboard Mars Odyssey [6] are in the same latitude zone and may be related to the mantle [7]. The thickness of this mantle is a few meters [3]. Our estimations show that this thickness is enough to explain smoothing and the prevalence of concave topography at high latitudes, if the mantle is properly deposited, and to explain prevalence of convex topography and slope asymmetry in the transitional zone, if the mantle is properly eroded.

There are additional phenomena exhibiting zonal occurrences whose relations to the surficial mantle and slope asymmetries have not been established. (1) The distribution or recent gullies [8] is highly correlated with these two zones of slope asymmetry; the individual gullies have too small area and do not influence the slope statistics, although may share an insolation-related origin. (2) The distribution of lobate debris aprons [9] and a number of related phenomena in this same latitude zones suggest that creep of a layer hundreds of meters thick has occurred. We are presently studying the relationship of these types of features to both the high-latitude mantling layer and the north-south slope asymmetries documented in this analysis.

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